Onion Creek Update, 2010

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Onion Creek, a major tributary to the Colorado River and significant contributor to the Edwards Aquifer recharge zone was sampled relatively intensively by the City of Austin and other agencies from 1995 to 2008. Water and sediment quality, as well as biological and physical assessments were conducted at sites from the headwaters in Northern Hays County to the confluence with the Colorado River in southeast Travis County. Onion's generally good water quality is influenced by the recharge zone which, during low flow periods, creates a break in flow between the upper and lower creek segments. There were few significant trends in water chemistry, with dissolved ions and nutrients increasing from upstream to downstream, and some dissolved ions increasing slightly over time. Biological measures were more robust, with several metrics showing a distinct longitudinal degradation from up to downstream. Inputs from the urban corridor as well as the creek's transition into the more erodable soils and unstable substrates of the downstream reach may be responsible for the lower quality biological communities downstream.

Introduction

Onion Creek, the largest of Austin's tributaries to the Colorado River, is approximately 75 miles in length with a drainage area of 350 square miles (COA 2002). It crosses two ecoregions, the Central Texas Plateau and the Blackland Prairie, and contributes about 46% of the total recharge to the Edwards Aquifer (Barrett, 1996). Approximately 20 percent of the total watershed drainage area lies over the aquifer recharge zone boundaries (Fig 2). It originates from springs in Blanco County, and flows eastward into Hays County, across the limestone bedrock of the Edwards Plateau. This upper watershed is relatively undeveloped and dominated by large ranches, many of which are increasingly being broken up and subdivided. The creek then flows into Travis County and over a major recharge area of the Barton Springs segment of the Edwards Aquifer, crossing into the Blackland Prairie ecoregion just downstream of IH-35, where the watershed becomes increasingly urbanized. Six of its eight tributaries contribute to this lower part of the creek as it flows towards its confluence with the Colorado River. The lower portion of the watershed is currently coming under added development pressure, associated in part with the Austin/Bergstrom International Airport and the "desired development zone" status of eastern Travis County as defined by the City of Austin's Land Development Code.

The City began monitoring Onion Creek in 1993, when the portion that flowed through McKinney Falls State Park was re-opened to swimming after several years of closures due to high fecal coliform levels from a now decommissioned wastewater treatment plant. For the next seven years, monitoring focused primarily on the middle portion of the watershed from IH 35 to the state park. In 2000, monitoring was expanded to provide a more complete assessment of the entire watershed.

This report includes analysis of land use, water and sediment quality as well as biological and physical habitat components of this monitoring effort. Data will be examined on a broad scale, by comparison with other watersheds evaluated through the City's Environmental Integrity Index (EII) and then through spatial and temporal changes within the watershed itself. The period of record is from 1995 with some sites added in 2000 and one added in 2005. Data from other agencies, including USGS, TCEQ and LCRA were included in portions of the analysis.

Land use and site selection

As shown in Figure 1, a majority of the land use (61%) in the Onion Creek watershed is categorized as undeveloped/agriculture, primarily as privately owned large parcel ranches. This has dropped from 1995, when the undeveloped category comprised 69% of land use (COA 2002). A corresponding change occurred in the residential category, which increased from 21% in 1995 to 29% in 2006. This confirms the general observation that large lot subdivisions are increasing in the upper, less developed portion of the watershed.

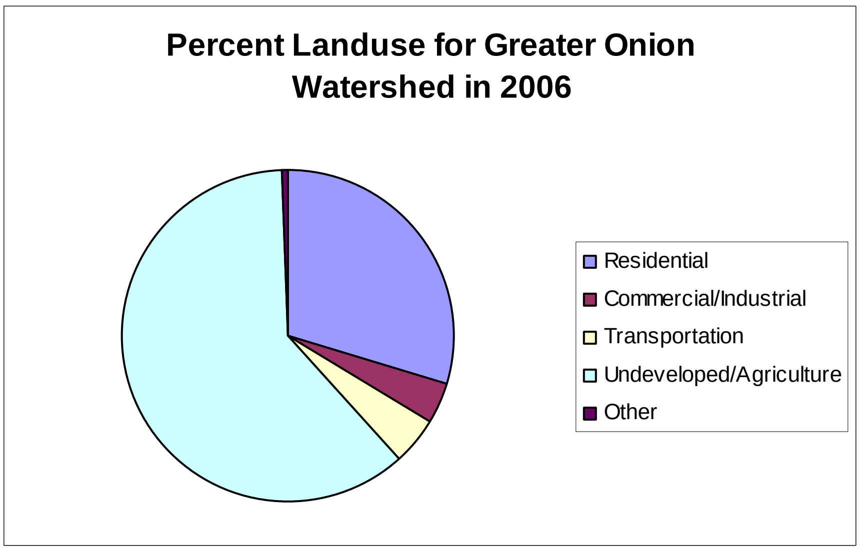

Figure 1. 2006 Onion Creek watershed land use distribution among 5 general groups.

To ensure comprehensive representation of this relatively large land area, sites were selected to represent major changes in ecoregion and land use within the watershed (Table 1). Within these segments, site selection was based on a variety of factors, including the presence of appropriate stream habitat (riffles), and access (typically bridge crossings, or with permission from private landowners). Proximity to USGS flow stations and availability of historical monitoring data were also considerations.

The Upper Onion segment ranges from the western headwaters in Blanco County to the eastern end of the Edwards Aquifer Recharge Zone. Onion @ Pfulman Ranch (#1365, PR) and Onion @ Hwy 150 (#612, Hwy 150) are both limestone bedded streams, overlain with alluvial substrate and cobble/gravel riffles; #1365 is a much smaller headwater stream with intermittent flow and a riparian zone somewhat impacted by cattle, while #612 is more perennial in nature, with large cobble riffles and deep perennial pools lined by large cypress trees. The area is dominated by large ranches and more recently, residential development around Dripping Springs and throughout northern Hays County.

The Middle Onion segment represents a transition out of the Central Texas Plateau ecoregion into the Blackland Prairie ecoregion, beginning at the eastern end of the recharge zone and continuing past Interstate Highway 35, still upstream of its urban tributaries. Onion @ Twin Creeks (#236, TC) has long stretches of limestone bedrock with periodic cobble/gravel riffles and shallow perennial pools. Onion above Footbridge (#241, FB) is on a golf course and has highly eroded banks and gravel/cobble substrate rather than bedrock and a riparian zone reduced to large trees and turf grasses (minimal understory or ground cover). This site is downstream of two tributaries, Bear Creek and Slaughter Creek.

The lower Onion segment is almost completely within the Blackland Prairie ecoregion, characterized by deeper soils and large open grasslands. It includes flow from all the urban tributaries, flows through

McKinney Falls State Park and finally ends at the confluence with the Colorado River. Onion @ McKinney Falls State Park (#255, MF) has limestone bedrock overlain with a large cobble/gravel riffle deep perennial pools and an extensive riparian zone; human impacts are limited due to the natural setting of the state park.. Onion @ SAR (#1365, SAR) is close to the confluence with the Colorado River and has extremely eroded banks and deep gravel/sand deposits, as well as more turbid flow and a heavily wooded riparian zone. At the very bottom of the watershed, this site captures the influence of all tributaries to Onion, and the Austin-Bergstrom International Airport.

Table 1. Site numbers, names and abbreviations for Onion Creek sampling sites

Site #	**Site Name**	**Abbreviations in this report**	**Segment Name**
1365	Onion Creek at Pfulman Ranch	Pfulman, PR	Upper Onion
612	Onion Creek Near Driftwood (Hwy 150)	Hwy 150	Upper Onion
241	Onion Above Footbridge	Footbridge, FB	Middle Onion
236	Onion Creek @ Twin Creeks Road	Twin Creeks, TC	Middle Onion
255	Onion Creek @ McKinney Falls Below Lower Falls	McK Falls, MF	Lower Onion
1366	Onion Creek @ South Austin Regional WWTP	SAR	Lower Onion

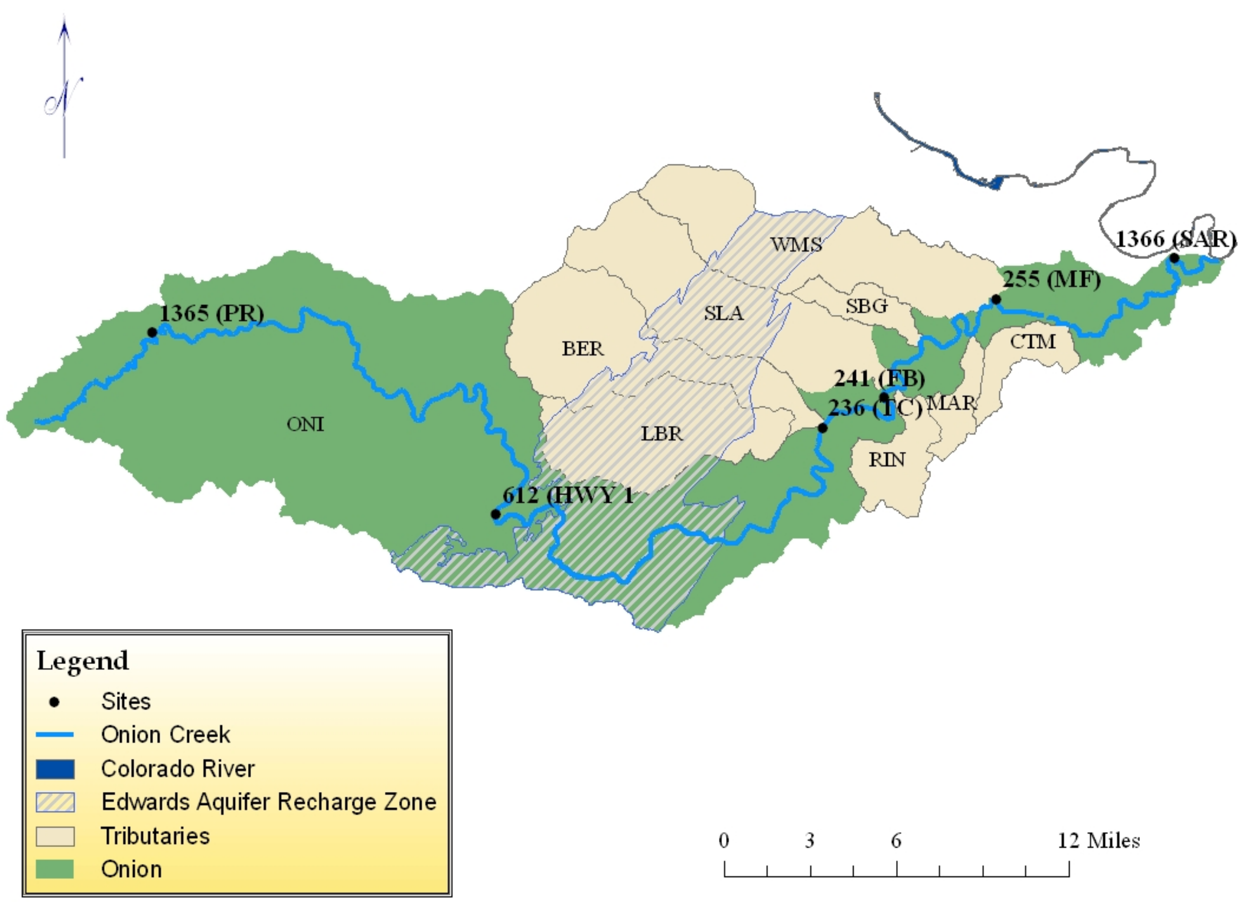

Figure 2. Onion Creek watershed, recharge zone and sampling sites

Methods

Water Chemistry
Stream monitoring was conducted according to WRE standard procedures (COA WRE SOP 2010) approximately three times per year at all sites, with quarterly sampling in 1998, 2001, 2004 and 2007 (EII phase years). See Table 2 for frequency details. Lab and field parameters are listed in Table 3; lab parameters were analyzed by the Walnut Creek Analytical Lab Services through 2005 and by the Lower Colorado River Authority Environmental Lab from 2005 to the present. Both labs are EPA/NELAC certified. Data from other agencies meets this same certification and are also required by TCEQ to meet Clean Rivers program requirements.

Table 2. City of Austin annual monitoring frequency for study components. .

Medium	**Frequency (per year)**	**Sampling Schedule**
Benthic Macroinvertebrate Community	2	May-Jun, Jul-Aug
Diatom Community	2	May-Jun, Jul-Aug
Habitat	2	May-Jun, Jul-Aug
Water Quality	4	Jan-Feb, May-Jun, Jul-Aug, Oct-Nov

Table 3. Laboratory and field constituents sampled during water chemistry surveys at six Onion Creek sites.

Parameter	**Method or Equipment**	**Analysis Location**
Dissolved Oxygen	Hach Hydrolab	Field
pH	Hach Hydrolab	Field
Temperature	Hach Hydrolab	Field
Conductivity	Hach Hydrolab	Field
Flow	Marsh-McBirney Flowmate	Field
Ammonia	EPA 350.1	Lab
Nitrate/Nitrite	EPA 353.2	Lab
Total Orthophosphorus	SM 4500-P F	Lab
TKN	EPA 351.2	Lab
TP	EPA 365.4	Lab
TSS	SM 2540 D	Lab
E Coli	SM 9222 G	Lab

Biological Monitoring
Biological monitoring was conducted twice annually at each site; see Table 1 for frequency details. Standard Rapid Bioassessment Protocols (COA WRE SOP 2010, Barbour et al. 1999) were followed in the collection and processing of benthic macroinvertebrate samples with the following exceptions:

- All organisms were sorted and preserved in the field, rather than in the laboratory.
- Surber samplers (500um mesh net) were used instead of kick nets.
- High abundance samples (>1000 orgs) were subsampled using a Caton subsampler.

Three replicate surbers were collected at each site from the bottom, middle and top of the study riffle, sorted discretely in the field and preserved for identification in the lab at a later date. Organisms from each sample were enumerated and identified to the lowest practicable taxonomic unit, usually genus. The following groups were not identified to genus: Chironomidae, Ostrocoda, Hydracarina, Hirudinea, and Oligochaeta.

Benthic macroinvertebrate metrics

The following metrics were calculated using Onion Creek benthic macroinvertebrate data and used for spatial and temporal analyses.

<u>EPT(Ephemeroptera, Plecoptera, and Trichoptera)/EPT + Chironimidae</u>
Uses the distribution of these major groups as a measure of community balance. Skewed populations have higher numbers of tolerant Chironomidae, possibly indicating environmental stress. (Plafkin, 1989)

<u># Ephemeroptera taxa, and % total as EPT (Ephemeroptera, Plecoptera, and Trichoptera)</u>
Both measure typically more sensitive taxa, and an increased number generally means increasing water quality.

<u>Hilsenhoff Biotic Index, HBI</u>
Sum of pollution tolerance values for all organisms, weighted by relative taxa abundance. Ranging from 0 to 10, where 1 is an intolerant, low nutrient community and 10 is an enriched, tolerant community.

<u>Trichoptera as Hydropsychidae</u>
Measures the relative abundance of pollution tolerant caddisflies, and increases as water quality decreases.

<u>Noninsect taxa</u>
Count of non-insect taxa, generally organisms considered to be more tolerant to a wide range of environmental conditions.

<u>Percent dominance</u>
Percent contribution of the numerically dominant taxon to the total number of organisms. Indication of community balance which is upset by a range of perturbations.

<u>Percent as collectors</u>
Percent contribution of the collector-gatherers to the total number of organisms. These organisms ingest fine particulate organic matter as their primary food resource, which typically increases with nutrient loads, but also increases with stream order.

<u>Intolerant Taxa</u>
Taxa richness of those organisms with tolerance values of $\leq$ 4.0 (TCEQ 2007) and considered sensitive to environmental perturbation.

<u>TCEQ qualitative aquatic life use index (ALU)</u>
Compiles 12 metrics: taxa richness, EPT richness, Hilsenhoff biotic index (HBI), percent Chironomidae, percent dominant taxon, percent dominant functional feeding group, percent predators, ratio of intolerant to tolerant taxa, percent of total Trichoptera as Hydropsychidae, number of non-insect taxa, percent collector-gatherers and percent of total as Elmidae. These 12 metrics are calculated and then are scored on a scale: > 36 Excellent; 36-29 High; 28-22 Intermediate; < 22 Limited (TCEQ, 2007).

Diatoms were collected and processed according to standard methods (COA WRE SOP 2010, Barbour et al. 1999). One rock was selected from the bottom, middle and top of the study riffle for a total of three rocks, and a fixed area of periphyton was scraped from each rock, then composited into a single sample bottle for enumeration and identification of the community to the species level by Winsborough Consulting.

Diatom metrics
The following metrics were calculated using Onion Creek diatom community data and used for temporal and spatial analyses.

Percent motile taxa
A siltation index showing the relative abundance of three genera (*Navicula*, *Nitzchia* and *Surirella*) that are able to move towards the surface if covered by silt (Stevenson, et al. 1999). The scoring scale of % motile diatoms was inverted to illustrate the relationship between high abundance and increased siltation as an undesirable result. (Muscio, 2002)

Pollution Tolerance Index (PTI)
Similar to the HBI for macroinvertebrates, using tolerance values weighted by relative taxa abundance, this metric responds primarily to nutrient enrichment (Stevenson, et al. 1999). Values increase as water quality increases, the inverse of the HBI, with values ranging from 1 for most tolerant to 3 for more sensitive species.

Cymbella Richness
Cymbelloid taxa richness (referred to as *Cymbella* for simplicity) highlights the presence of sensitive species and increases with increasing water quality (Muscio, 2002).

Habitat Assessment
Physical characterization of the stream sites, including riffle, reach and riparian zone assessment was completed three times, in 2005, 2006 and 2007, using a modified version of the EMAP habitat assessment method (City of Austin, 2010). In addition, during each benthic macroinvertebrate survey, the EPA RBP visual Habitat Quality Index method was used to generally inventory habit quality (Barbour et al. 1999). Both of these data sets were used to compare overall habitat quality and spatial differences among sites and in the interpretation of the biological data.

Data Analysis
Water quality data collected from 1998 to 2009 was analyzed for spatial and temporal trends for individual parameters. Parameters analyzed for spatial analysis included alkalinity, ammonia, chloride, conductivity, dissolved oxygen, E. coli bacteria counts, fecal coliform bacteria counts, flow, orthophosphorus, phosphorus, pH, sulfate, total kjeldahl nitrogen (TKN), total suspended solids, turbidity, and water temperature. Site #241, Onion Creek at the Footbridge, was excluded from the spatial analysis for chloride, fecal coliform bacteria, total kjeldahl nitrogen (TKN), phosphorus, and turbidity because insufficient data existed at this site for these parameters.

Spatial analysis was also performed on benthic macroinvertebrate and diatom metrics calculated from samples collected beginning in 1998 on Onion Creek. The analysis was based on the data collected from 1998 to 2009 for both sets of data. Benthic macroinvertebrate metrics include number of organisms, number of taxon, number of diptera taxa, number of ephemeroptera taxa, number of ept taxa, number of noninsect taxa, number of intolerant taxa, percent dominance (top 1 taxa), percent dominance (top 3 taxa), hilsenhoff biotic index, percent of total as chironomidae, percent of total as elmidae, percent of total as ept, percent of total as collector/gatherer, percent of total as predator, percent of total as filterers, percent of total as grazers, percent of trichoptera as hydropsychidae, ratio of intolerant of tolerant organisms, percent of total as tolerant organisms, percent of total as dominant guild, ept/(ept + chironomidae), TCEQ quantitative aquatic life use score, and TCEQ qualitative aquatic life use score. Diatom metrics include number of taxon, pollution tolerance index, cymbella richness, percent motile taxa, and percent similarity to a reference condition.

The distribution of water quality, benthic macroinvertebrate, and diatom data was checked for normality by the Shapiro-Wilk test in SAS. Analysis of Variance was carried out on the parameters with a normal distribution while a Kruskal-Wallis test was performed on the non-normally distributed parameters to examine whether or not a difference existed between sites for a given parameter. To examine which sites were significantly different for each parameter a Tukey-HSD multiple comparison test was performed on parameters where a significant difference existed according to an ANOVA. The minimum p-value multiple comparison test was performed on parameters where a significant difference existed according to a Kruskal-Wallis test. All alpha levels were set to 0.05 for this analysis. Means for water quality data that contained no censored data (less than detection limit values), benthic macroinvertebrates, and diatoms were calculated using PROC MEANS in SAS, while the Kaplan-Meier technique (PROC LIFETEST in SAS) was used to calculate means for parameters with censored data.

The water quality, benthic macroinvertebrate, and diatom data were analyzed for temporal trends from 1998 to 2009. Parameter data that was normally distributed was analyzed using least squares regression with the PROC REG procedure in SAS, while data that was non-normal was ranked first and then analyzed using least squares regression. Water quality data that contained censored values were analyzed using Cox's proportional hazards regression in SAS using the PROC PHREG procedure. Alpha levels were set to 0.1 for temporal analysis. Only significant trends were presented in this report.

Results

Environmental Integrity Index

Onion Creek is evaluated as part of the City of Austin's Environmental Integrity Index, a program that combines biological and physical criteria with chemical and sediment data to provide a comparative analysis of area creeks on a three year rotating basis. Scores were calculated and placed in the following narrative categories:

0-12.5 = Very Bad	12.6-25 = Bad	25.1-37.5 = Poor	37.6-50 = Marginal
50.1-62.5 = Fair	62.6-75 = Good	75.1-87.5 = Very Good	87.6-100 = Excellent

Onion Creek scored third highest of all creeks (79 out of 100, in the very good category) with only Bee and Bull Creeks scoring higher (Figure 3). This is due in part to Onion's high quality benthic macroinvertebrate community, which scored in the excellent category at all sites. The most upstream site, Pfulman, had the lowest, or best, Hilsenhoff Biotic Index (HBI) score (2.89) of any site from all creeks in the program in 2007 (City of Austin, 2007).

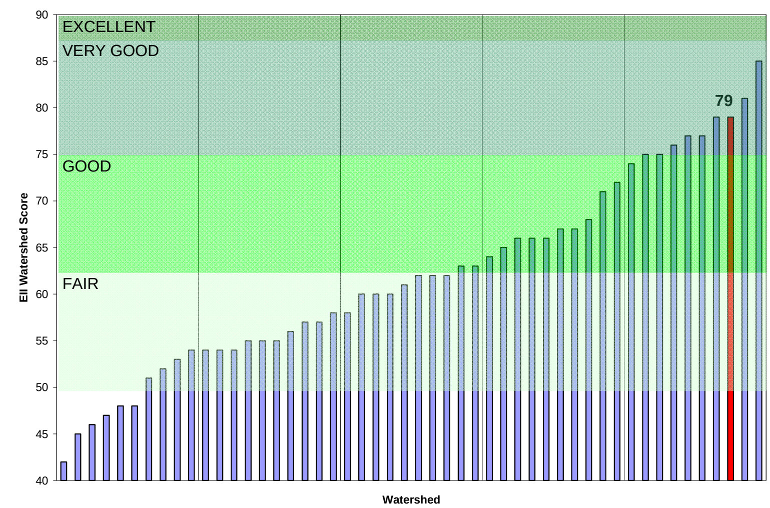

Figure 3. 2006-2008 EII watershed scores for all watersheds, with Onion in red.

Onion EII sediment scores are excellent to very good in recent years as shown in Figure 4. The low values in 1996 and 1998 were due to high values for PAHs at Onion @ Footbridge (#241), but temporal comparisons are difficult, as this site was only monitored in those two years and the source of these PAHs was never determined.

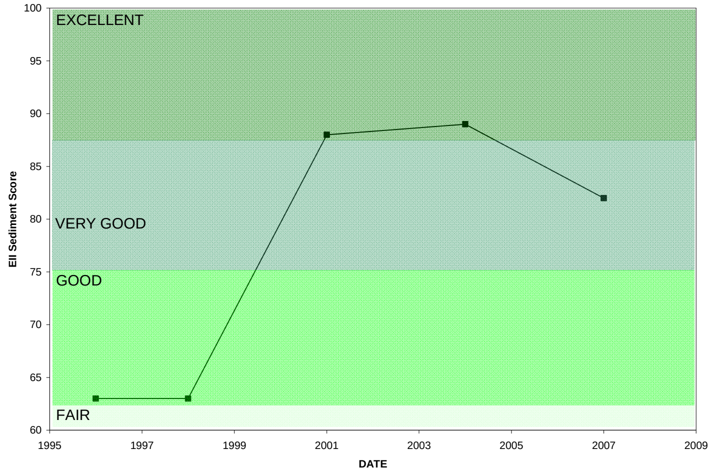

Figure 4. Onion Creek EII sediment scores. 1996-2007.

Overall EII scores on Onion Creek shown in Figure 5 have generally remained in the “Very Good” category (75-87.5), although there appears to be a drop in the contact recreation subindex recently, which resulted from a program-wide switch from fecal coliform to *E coli* as the indicator parameter in 2004. The aquatic life subindex score has increased consistently since 1998.

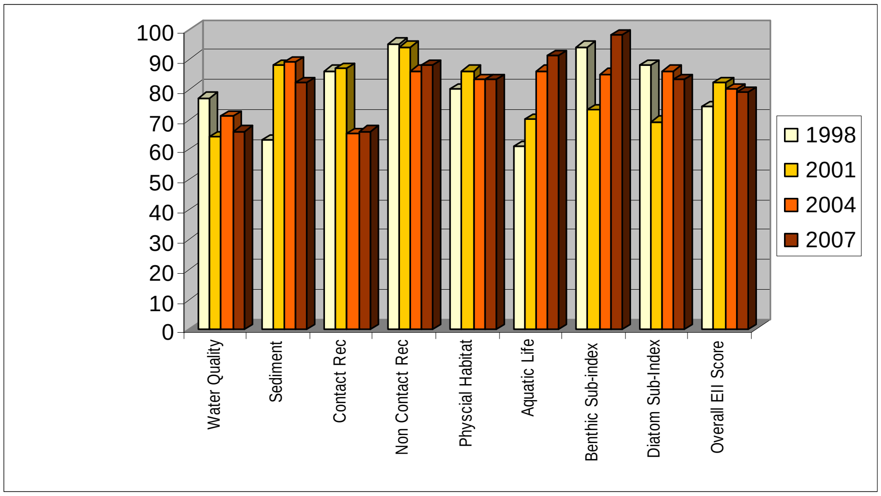

Figure 5. EII subindex and overall scores for Onion Creek, 1998-2007

Water chemistry spatial trends

There were not many significant water chemistry differences among sites on Onion Creek. A significant spatial pattern was present for conductivity (Fig 6) between the three upstream (PR, Hwy 150 and TC) and three downstream sites (FB, MF and SAR), which increased from a mean of 487.9 uS/cm at Pfulman to 582 uS/cm at Footbridge.

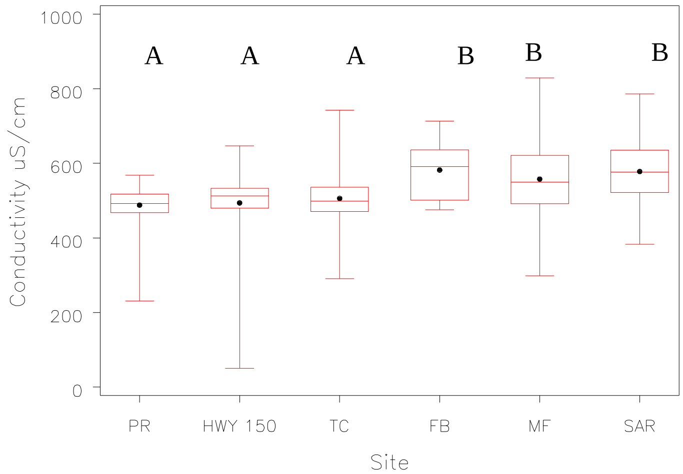

Figure 6. Boxplot of conductivity (uS/cm) for all sites on Onion Creek, 1998-2008. Dots within the box represent the sample mean while the lines within the boxes represent the sample median. Different letters for each site represent a significant difference between sites for conductivity.

This trend is mirrored in the dissolved ions, chloride and sulfate (Fig 7). Both parameters show a visual trend of general increase from up to downstream, with a significant drop in chloride means between McKinney Falls (MF) and the most downstream site, SAR. For chlorides and sulfates, the two upper sites (PR and Hwy 150) are similar to each other, but significantly different from the lower sites. The mean for chlorides at McKinney Falls is significantly higher than all other sites (37.19 mg/L). Data from all sites are well below TCEQ's standard of 100 mg/L for both parameters.

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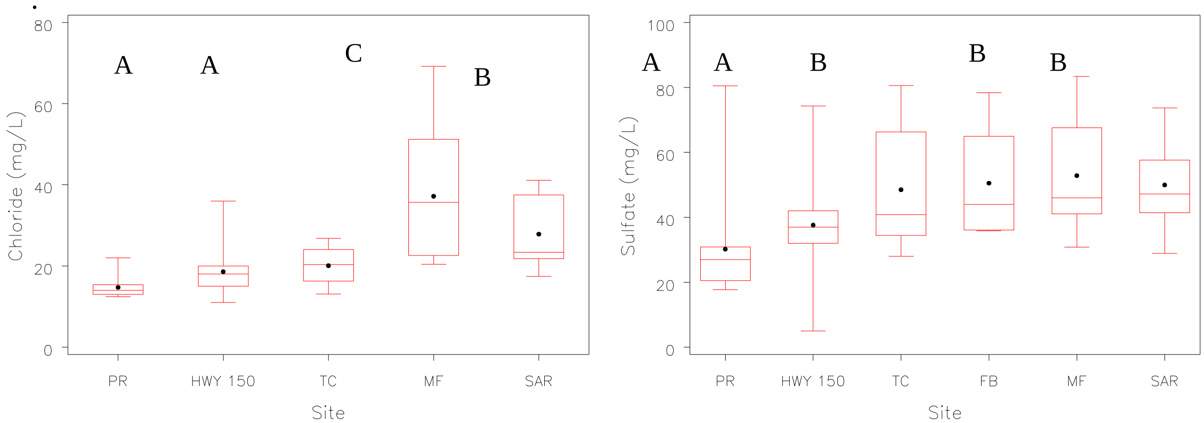

Figure 7. Distribution of chloride and sulfide ion concentrations for all sites on Onion Creek, 1998-2008. Dots within the box represent the sample mean while the lines within the boxes represent the sample median. Different letters for each site represent a significant difference between sites for these ions.

While *E. coli* shows no significant spatial trend, it is important to note that all site means are below the TCEQ contact recreation standard of 126 col/100 mL (Fig 8). The disproportionate number of data points at McKinney Falls (MF) is due to the Texas Parks and Wildlife Department's intensive data collection program designed to provide the state park users information about swimmability.

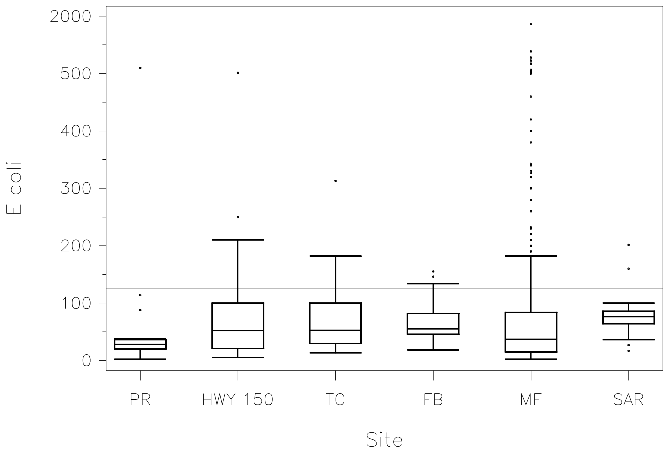

Figure 8. Boxplot of *E coli* concentration (colonies/100mL) at Onion Creek sites, 2000-2009. Horizontal line indicates TCEQ contact recreation standard of 126 col/100mL, and the Y axis has a break between 500 and 2000 to represent entire range. Lines within the boxes represent sample means, boxes the 25th to 75th percentile and whiskers 1.5 x interquartile range.

Downstream sites showed higher means for some nutrient parameters (Table 4). For ammonia, FB has the highest mean (0.051 mg/L) and is significantly different from all other sites while MF has the next highest mean (0.038 mg/L) but is not different than the most downstream site (SAR). Nitrate+nitrite as N (NO3+NO2) shows an increasing and significant downstream trend, with SAR having the highest mean (1.705 mg/L), significantly diff from all other sites, and PR being the lowest and significantly different from all other sites (0.97 mg/L). The TCEQ screening criteria is not exceeded by the mean of any of the nutrient or TSS parameters.

Table 4. Means, standard deviation (STD) and letters indicating significance groupings (SIG) for nutrients and TSS on Onion Creek sites, which are in order of upstream (left) to downstream (right). State screening levels are provided for reference (TCEQ SCR). Shaded cells indicate highest means for NH3 and NO3+NO2. N/A indicates no data.

	TCEQ SCR	PR			Hwy 150			TC		
PARAM	**mg/L**	**MEAN**	**STD**	**SIG**	**MEAN**	**STD**	**SIG**	**MEAN**	**STD**	**SIG**
NH3	0.33	0.028	0.003	A	0.026	0.005	A	0.028	0.002	A
NO3+NO2	1.95	0.097	0.015	A	0.24	0.041	B	0.445	0.117	B
OP	0.37	0.038	0.006	B	0.018	0.005	A	0.029	0.006	AB
Total P	0.69	0.02	0		0.022	0.006		0.043	0.015	
TKN	NA	0.171	0.019		0.218	0.022		0.342	0.069	
TSS	NA	1.22	0.26		1.77	0.31		13.86	11.33	

		FB			MF			SAR		
PARAM	**mg/L**	**MEAN**	**STD**	**SIG**	**MEAN**	**STD**	**SIG**	**MEAN**	**STD**	**SIG**
NH3	0.33	**0.051**	**0.009**	**C**	0.038	0.003	B	0.032	0.002	AB
NO3+NO2	1.95	1.037	0.303	C	0.7	0.14	C	**1.705**	**0.214**	**D**
OP	0.37	0.031	0.011	AB	0.032	0.009	AB	0.041	0.008	B
Total P	0.69	N/A	N/A		0.031	0.006		0.043	0.014	
TKN	NA	N/A	N/A		0.267	0.033		0.273	0.041	
TSS	NA	4.21	1.85		3.26	0.35		8.07	1.04	

Water chemistry temporal trends

The few significant temporal trends in the Onion Creek watershed are in dissolved ions, particularly chlorides and conductivity (Fig 9).

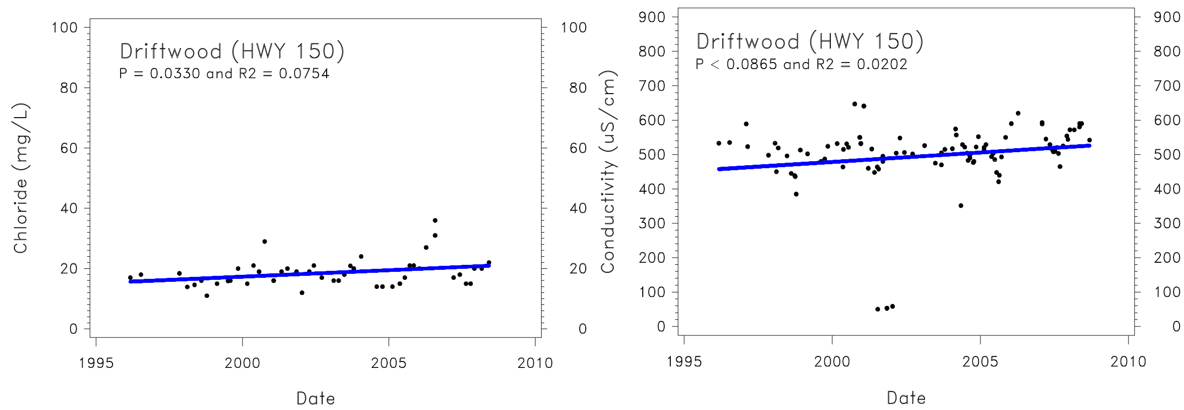

Figure 9. Linear regression for chloride ions and conductivity, 1998-2008, Hwy 150, Onion Creek. P-values and R^2 values are noted on each graph.

Conversely, chlorides and sulfates are both decreasing significantly over time at McKinney Falls (Fig 10), although the smaller data set limits the comparison. Conductivity, a much larger data set, shows more subtle decrease over a longer period than for the other dissolved constituents.

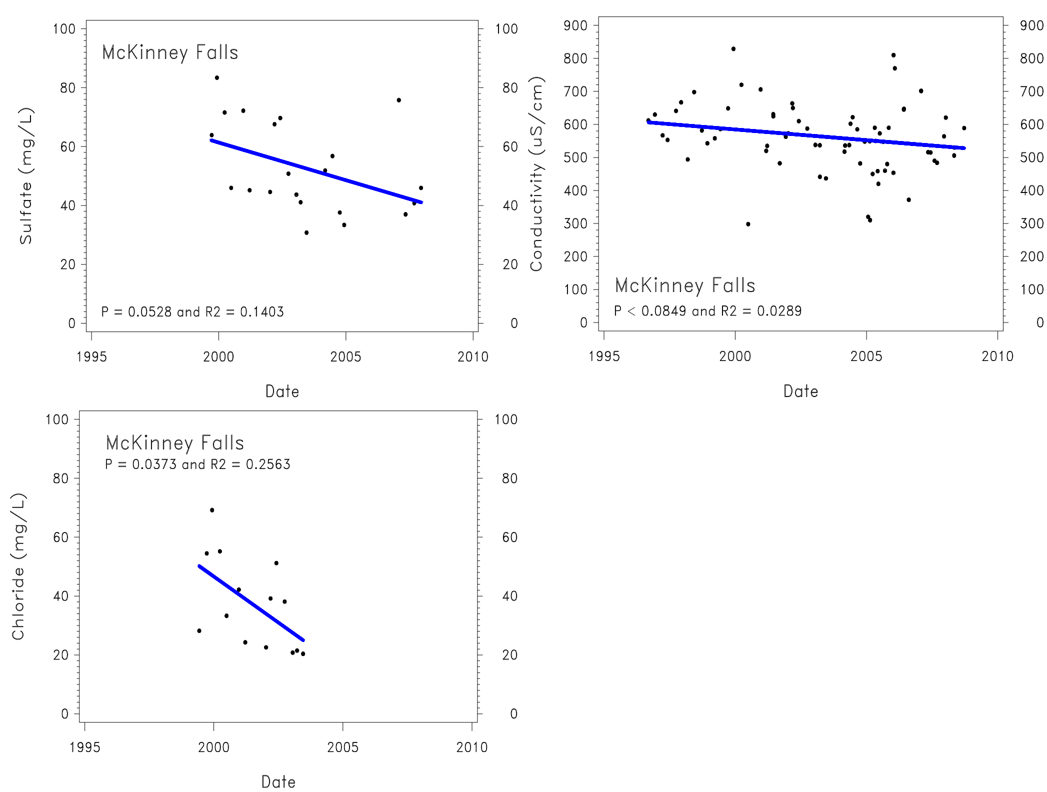

Figure 10. Linear regression of sulfate 1999-2007, conductivity 1998-2008, and chloride 1999-2003, McKinney Falls, (MF) Onion Creek. P-values and R^2 values are noted on each graph.

Biological Data
Biological communities can provide an integrated measure of environmental stresses and fluctuations in a stream. Benthic macroinvertebrates' relatively long aquatic life spans (months to years) and varying tolerance to pollution allow for a more complete picture of stream health than may be obtained from the 'snapshot' of basic water chemistry data. Diatoms are the primary component of periphyton, or attached algae, in flowing streams; with their short life cycles (days to weeks) and quick response to environmental changes, they also have a range of tolerances that are useful in characterizing stream health.

Benthic macroinvertebrate spatial trends
Onion Creek showed a general longitudinal decline in biological community health from upstream to downstream, with both Pfulman and Hwy 150 (upper watershed sites) showing differences in some of the metric scores from the mid and lower watershed sites.

Highway 150 showed significantly higher scores for three EPT- related metrics as well as the lowest mean HBI score among all sites (Fig 11). Other metrics also show a significant difference between upstream and downstream sites but these have the headwaters site Pfulman, rather than Hwy 150, as the site with the best score. Pfulman had the lowest mean of Trichoptera as Hydropsychidae, a pollution tolerant caddisfly, as well as the lowest mean of noninsect taxa, a measure of more tolerant organisms (Fig 12).

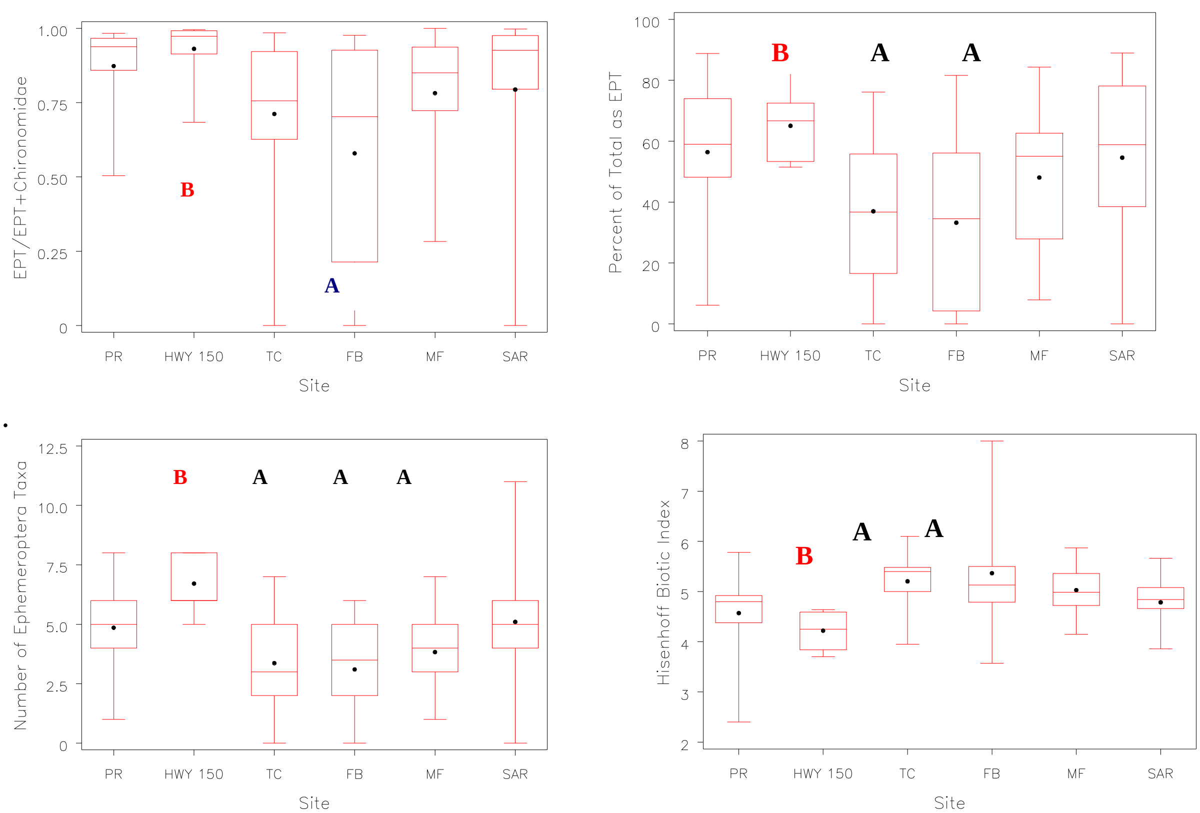

Figure 11. EPT/EPT Chironomidae, # EPT, % Total as EPT and HBI metrics showing Hwy 150 (B) as significantly different from lower sites (A). Absence of letters means no significant difference with any other site. Dots represent the sample mean while lines within the boxes represent the sample median. Different letters for each site represent a significant difference between sites.

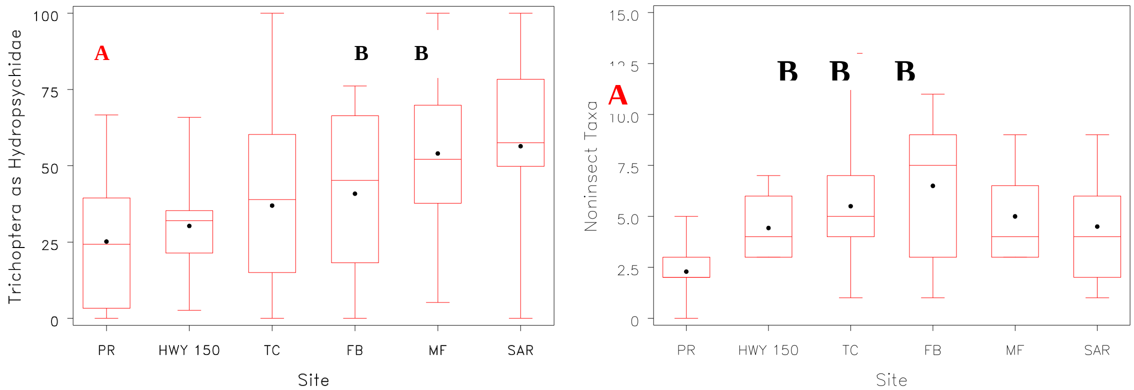

Figure 12. Trichoptera as Hydropsychidae and number of noninsect taxa for Onion Creek sites, showing Pfulman (A) as significantly different from mid and lower watershed sites (B). Dots represent the sample mean while lines within the boxes represent the sample median. Different letters for each site represent a significant difference between sites.

One robust measure that shows no significant spatial trend but still provides a framework for evaluating Onion Creek's health is TCEQ's Aquatic Life Use index(ALU) which shows the overall mean of each Onion site in the 'High' category, scoring between 29 and 36 points (Fig 13).

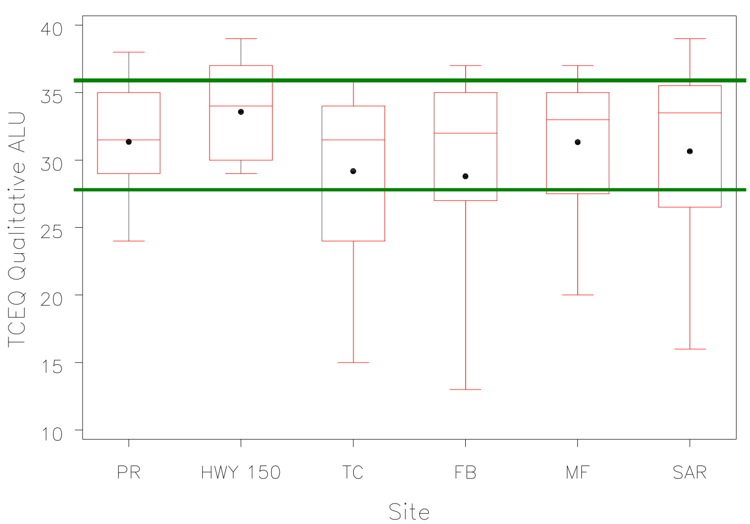

Figure 13. TCEQ Qualitative ALU for all sites on Onion Creek. Green lines indicate the boundaries for the High category, ranging from 29-36 points. Dots represent the sample mean and lines within the boxes represent the sample median.

Diatom Spatial Trends

This community shows a distinct difference between upstream and downstream sites, in particular with percent motile taxa and PTI (Fig 14). Percent motile shows a progressive increase, or water quality decline, from upstream to downstream. The upper watershed sites are significantly different from the lower, while the mid watershed sites share similarity with both upper and lower sites. PTI shows a more distinct break from up to downstream, with PR, Hwy 150 and TC similar to each other and significantly different from MF and SAR, again demonstrating a decline in water quality from upstream to downstream.

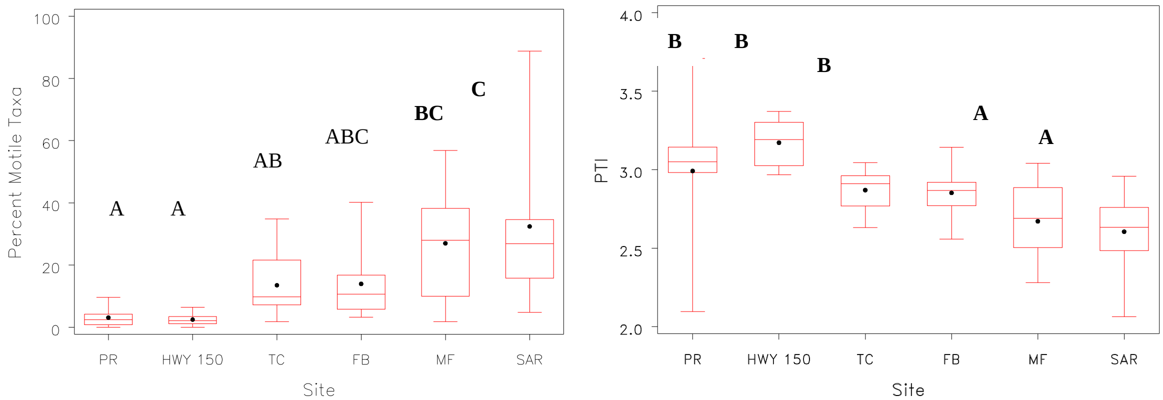

Figure 14. Boxplot of Percent Motile Taxa and Diatom PTI for all Onion sites,. Dots represent the sample mean while lines within the boxes represent the sample median. Different letters for each site represent a significant difference between sites. Sites which do not have a letter are not significantly different from any other site.

Biological temporal trends

All sites but Hwy 150 and FB showed significant improving trends over time in one or more benthic macroinvertebrate metrics. In particular, these sites showed a decrease in HBI scores (Figure 15), which often indicates a decrease in organic enrichment. PR showed the steepest decline, with the lowest HBI score of all Austin area creeks sampled in 2007 (City of Austin, 2007).

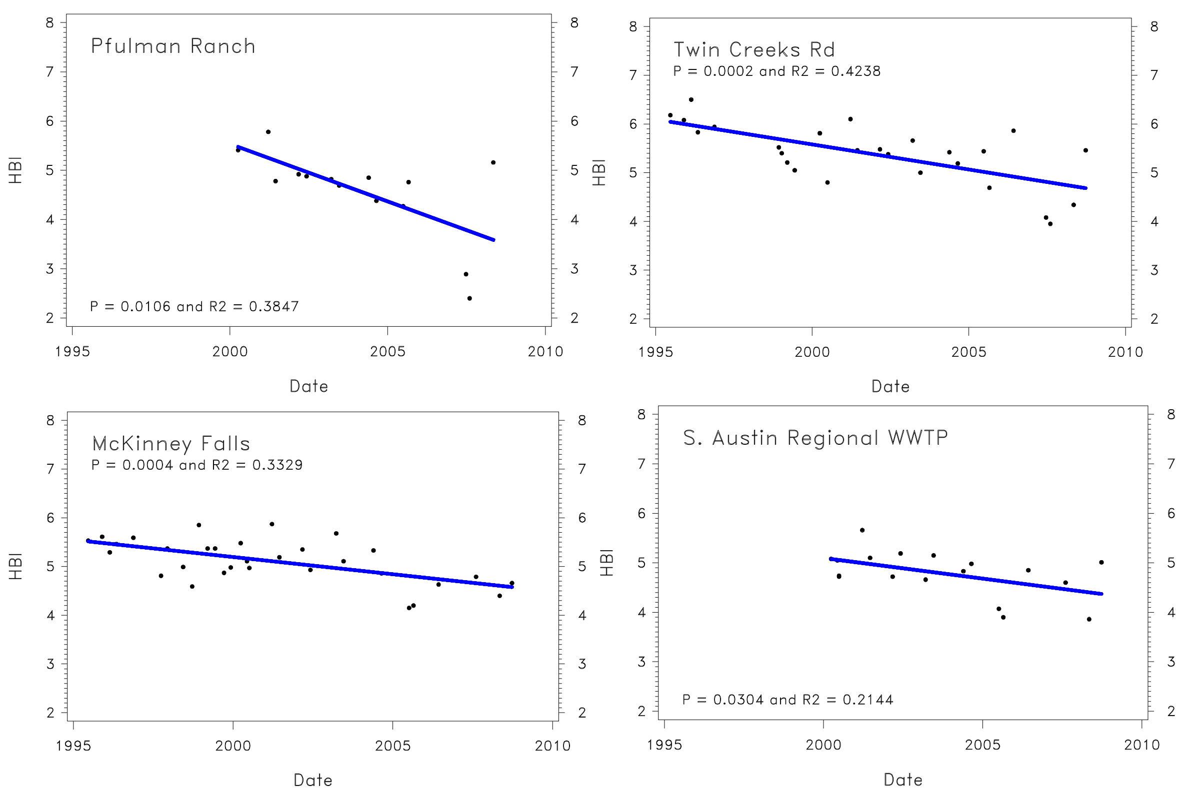

Figure 15. Linear regression of HBI for Pfulman, Twin Creeks, McKinney Falls and SAR, Onion Creek. Period of record varies by site. P-values and R^2 values are noted on each graph

Besides HBI, several other benthic macroinvertebrate metrics showed improvment over time at Onion sites (Figs 16). Twin Creeks is the only site that showed a temporal trend (improving) in the diatom community, as *Cymbella* richness increased and SAR was the only site to show a potentially degrading temporal trend, as percent collectors increased over time (Fig 17). Above Footbridge had a ten year gap in benthic macroinvertebrate sampling, with no data collected between 1995 and 2005. While there was one decreasing trend (Trichoptera as Hydropsychidae) at this site, indicating improvement, the ten year gap makes this trend difficult to interpret.

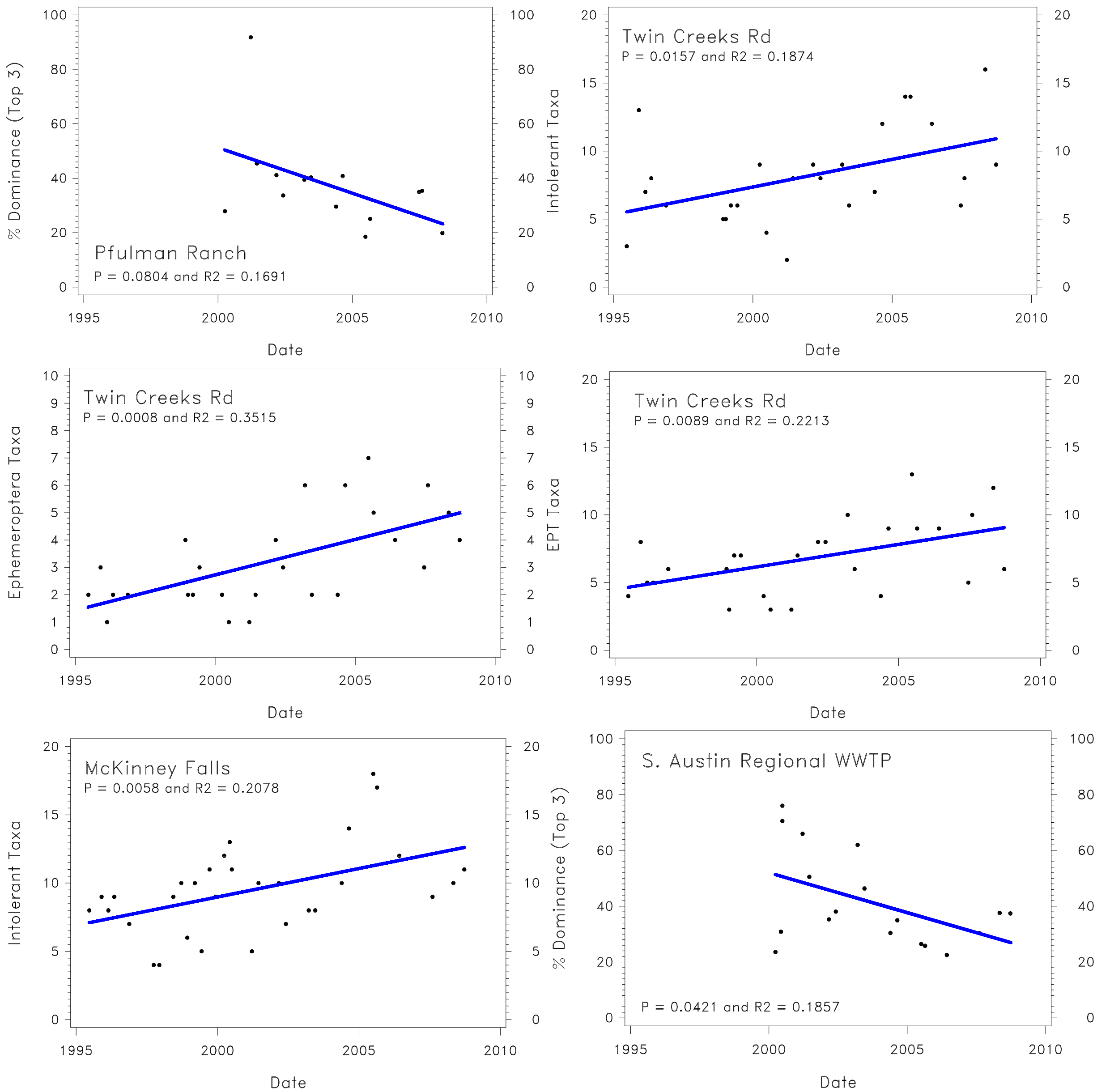

Figure 16. Linear regression plots of various metrics at Onion Creek sites, 2000-2008 showing improvement in stream health: Percent Dominance (top 3 taxa) at Pfulman and SAR, number of intolerant taxa at Twin Creeks and Mckinney Falls, and number of Ephemeroptera taxa at Twin Creeks. Alpha-level (p-value) and R^2 value are noted on each graph.

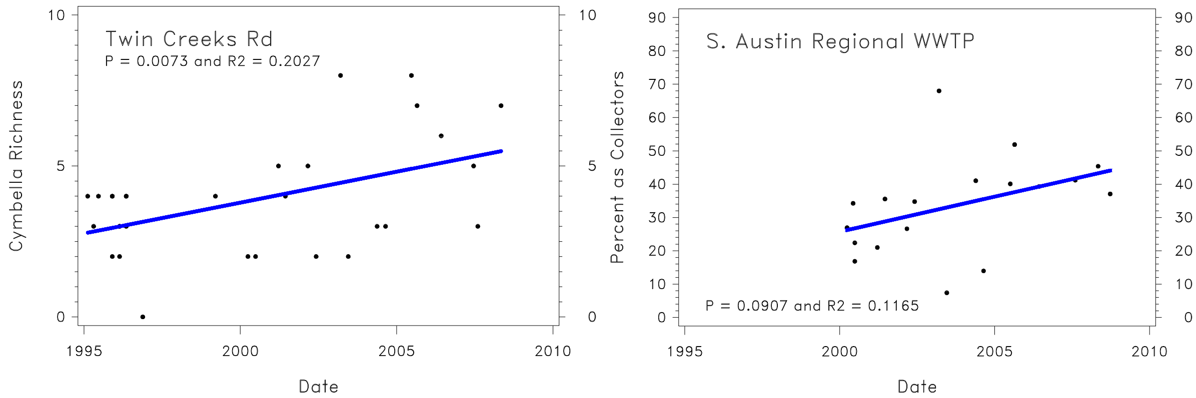

Figure 17. Linear regression of *Cymbella* Richness (diatoms) at Twin Creeks, 1995-2008 and percent collectors (benthic macroinvertebrates) at SAR, 2000-2008. P-values and R^2 values are noted on graph.

Habitat

All benthic macroinvertebrate and diatom samples were collected from riffle habitat, shallow, high gradient areas of the stream, typically dominated by cobble/gravel substrate. Riffle characteristics differed somewhat between sites, but were documented with pebble counts, instream cover estimates and length and width measurements during four annual surveys from 2005-2008.

Substrate size distribution (measured with pebble counts, Bevenger and King 1995) is one of several physical factors influencing stream biota; particle size and interstitial spaces are important for providing refugia, surface-area for periphyton growth and trapping organic detritus. While some species are highly restricted in their preference for a particular substrate size class, in general, benthic macroinvertebrate diversity and abundance increase with substrate heterogeneity, stability and particle size (Allen, 1995). Sand and other unstable substrates are less beneficial for most organisms due to their tendency to shift and settle, which limits oxygen, detritus and habitat availability.

Riffle habitat at Onion sites had a variety of substrate sizes, with no single size class over 35% of the total count (Fig 18). McKinney Falls (MF) had the most large cobble (12 %) and HWY 150 has nearly 35 % small cobble. The other sites have close to 30 % of the next smallest size, very coarse gravel. Footbridge (FB) substrate is noticeably tilted towards the finer substrate size, with no large cobble, only 4% small cobble and 17% silt. Twin Creeks (TC) and SAR have the next two highest percent silt (8 and 4 % respectively).

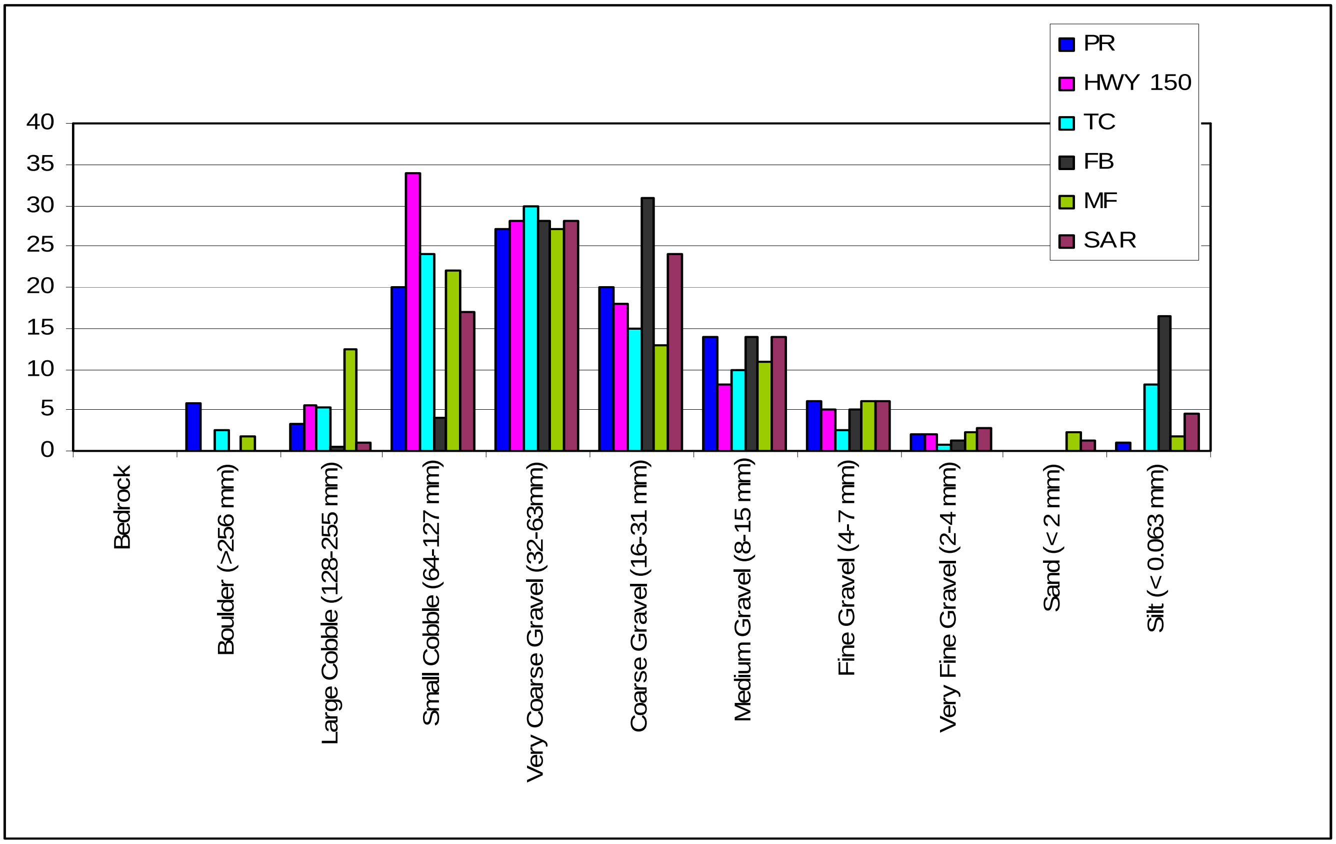

Figure 18. Average substrate size class distribution at Onion Creek sites 2005-2008 (n=4).

Instream cover, or the type and amount of structure within the wetted stream channel, is another measure of available benthic habitat (Lazorchack et al. 1998). It was estimated on a 0-4 scale, with 1 being sparse (up to 10% cover) and 4 being dense (more than 75% cover), and includes both organic (woody debris, roots, terrestrial vegetation) and inorganic materials (undercut banks, bedrock ledges, cobble and boulder). Total instream cover is fairly sparse at all Onion study sites, with the highest average score of 1.26 at MF (Fig 19). Cobble and boulder was the only portion of instream cover providing any score above 2 (10-40%), with most other types scoring less than 1.5. PR, HWY 150 and MF are the only sites having scores of 2.5 or higher for Cobble and Boulder.

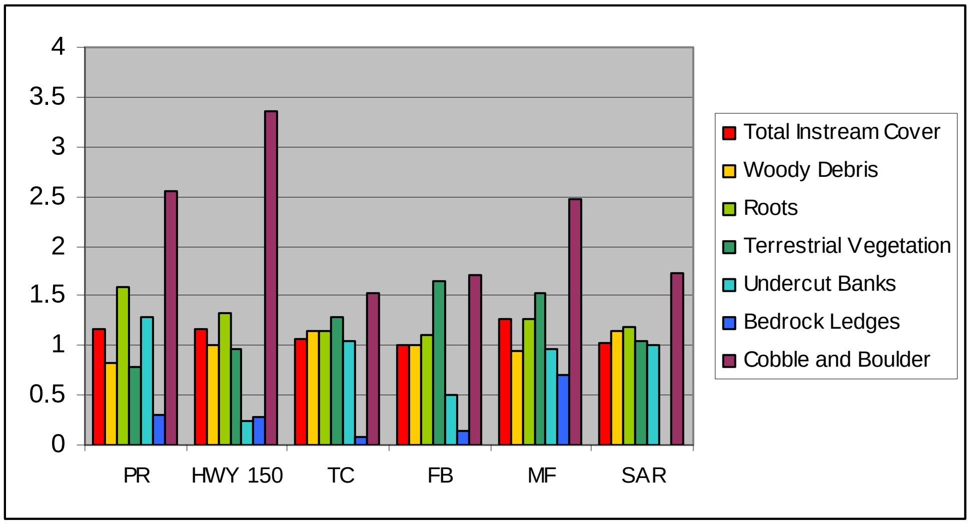

Figure 19. Available instream cover on a relative scale of 0-4 at Onion Creek sites, 2005-2008.

The reach length at each site was determined by calculating 40 X the average wetted width at the riffle (Barbour et al 1999). At each site, the number of runs, riffles and pools was generally similar, three or four of each habitat unit, with some exceptions (Table 5). The headwater site, PF, had a much shorter reach, but a similar number of habitat units as other sites. The smallest riffle was at Twin Creeks (419 sq ft), while Hwy 150 had the largest riffle (2266 sq ft) of all sites. The relationship between riffle area and reach length is shown in Figure 20, with Twin Creeks having the least amount of riffle per foot of reach, while Pfulman is actually closer in this measure to the more downstream sites.

Table 5. Riffle and Reach Characteristics, all Onion Creek sites, 2005-2008.

	Pfulman	Hwy 150	Twin Creeks	Footbridge	McK Falls	SAR
Runs	2	4	2	1	2	3
Riffles	3	4	3	3	3	4
Pools	5	4	3	3	4	4
Reach Length (ft)	461.6	1443.0	945.4	940.0	953.2	887.3
Riffle Length (ft)	37.0	60.8	26.6	50.6	53.8	58.1
Riffle Area (ft^2)	437.1	2266.6	419.0	953.7	1236.2	1124.0

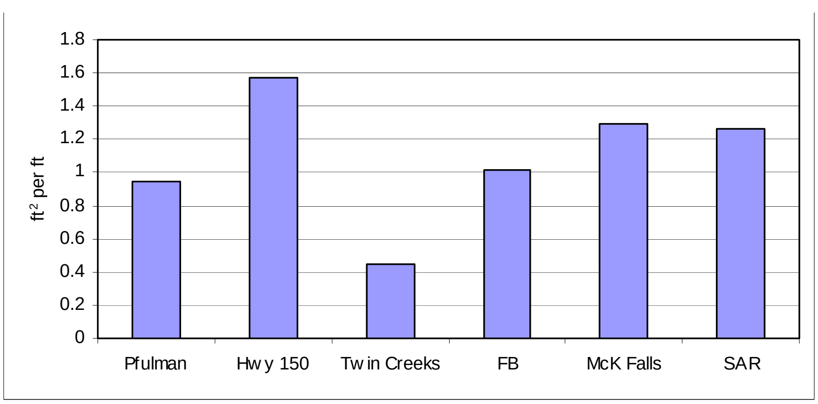

Figure 20. Average Riffle area per foot of reach length, at Onion Creek sites, 2005-2008.

Discussion

Spatial Patterns
Conductivity, chlorides and sulfates all show a distinct increasing trend from upstream to downstream, with conductivity significantly lower at the three upstream sites than the three downstream sites (Fig 6). This longitudinal difference could be due in part to the Edwards Aquifer Recharge Zone, which falls between the upstream site Hwy 150 and Twin Creeks as shown in Figure 2. At certain flow rates, a portion of the creek goes dry as it passes through the recharge zone, creating a 'break' between the upper and lower creek segments, with flow immediately downstream of this zone highly influenced by springs. This groundwater influence with higher dissolved ions could be a factor in the increasing downstream trend in conductivity and related parameters.

Nitrate+nitrite showed an increasing downstream trend, with means ranging from 0.097 mg/L at the most upstream site (PF), to a mean of 1.70 mg/L at the most downstream site (SAR), approaching the TCEQ screening criteria of 1.95 mg/L (Table 3). Other significant differences were seen in ammonia, with FB having the highest value, 0.051 mg/L and orthophosphorus, with SAR again having the highest value (0.041 mg/L), but no other spatial trends were seen. Means from all sites for ammonia and orthophosphorus were at least a factor of ten below the TCEQ screening criteria. Besides the recharge zone influences, increasing downstream trends in both nutrients and dissolved ions could be due in part to inputs from the urban corridor, as well as the transitional nature of Onion Creek as it flows across two ecoregions, the Central Texas Plateau upstream and the Blackland Prairie downstream. The upper sites (PR and Hwy 150) are upstream of the recharge zone and within the Central Texas Plateau, having similar limestone bedded substrate and more open riparian zones. SAR, the most downstream site, is more typical of the Blackland Prairie ecoregion, with deep, highly eroded soils and dense riparian vegetation. This transition status between not only the recharge zone but also the ecoregions was evident in the two middle watershed sites, (TC and FB) which independently tracked with the upper watershed sites for some parameters (TC- conductivity, ammonia, nitrate+nitrite) and with the lower watershed sites for others (TC- sulfates, FB-conductivity, nitrate+nitrite).

While spatial differences in water chemistry on Onion Creek involve only a few parameters, biological metrics show a more distinct longitudinal decrease in watershed health from up to downstream, as both Pfulman and Highway 150 (upper watershed sites) had several significantly better mean metric scores than all downstream sites. Highway 150 showed significantly higher scores for three EPT- related metrics, indicating a good representation of sensitive taxa, as well as the lowest mean HBI score, which can increase with an increase in organic pollution. Pfulman, the headwaters site, had significantly lower means for two metrics, Trichoptera as Hydropsychidae and non-insect taxa, both indicating a more sensitive insect community. Both sites had significantly better mean diatom metrics than downstream sites as well, further supporting the patterns observed in the macroinvertebrate community. The upper portion of the watershed, although experiencing some development pressure, is still maintaining a healthier biological community than downstream areas. Nutrient loading from tributaries in the urban corridor as well as the creek's transition into the more erodible soils of the Blackland Prairie ecoregion may be responsible for this spatial pattern.

The percent motile diatom metric demonstrates the ecoregion transition well. On Onion Creek, this metric increases significantly from upstream to downstream, where the deeper soils and higher flood flows result in increased siltation. Thus the most downstream site SAR has the highest mean of all sites, with a maximum value of 90%, while both Pfulman and Hwy 150 have means of less than 10%. Besides general ecoregion influences, riffle quality can play a role in determining biological community health. With significantly better scores for four biological metrics, Hwy 150 also has the largest riffle area and the most cobble and boulder as instream cover (Table 5). Twin Creeks has the smallest riffle per foot of reach (Fig 24) while Footbridge, with poorer scores for many metrics, has a riffle substrate tilted towards finer substrate size, with the least amount of cobble of all sites, and the largest percent silt (Fig 23).

Even as biological metric scores decrease longitudinally, it is important to note that Onion Creek sites do not overall have substantially impaired biological communities. As shown in Fig 16, most sites have a mean TCEQ Qualitative Aquatic Life Use (ALU) score that is considered "High" (30-36). Only Twin Creeks and Footbridge in the middle portion of the watershed have means near or below the boundary between High and Medium, and these may be explained by the riffle limitations described previously. This high quality biological community is most likely due to the large percentage of the watershed still undeveloped or in large parcel ranches. In addition, downstream of the urban corridor of Austin with its contributions from densely developed tributaries, the extensive, healthy riparian zones of McKinney Falls State Park and Onion Creek Preserve may provide additional benefits to the aquatic communities.

Temporal Trends

Dissolved ions show the only temporal trends in water chemistry on Onion Creek for the period of record of this report. Both chlorides and conductivity are increasing over time at Hwy 150, possibly due to a shift in land use from large ranches to smaller parcel suburban development in the upper watershed. Chlorides and sulfates at McKinney Falls show a significant but decreasing temporal trend, possibly influenced by flooding/high flow periods during the more limited data set (2000-2008 for sulfate, 2000-2004 for chlorides), while conductivity with a longer period of record (1996 – 2008) shows a much slighter decrease.

All sites but Hwy 150 and Footbridge showed significant temporal improvements in one or more benthic macroinvertebrate metric. In particular, HBI improved at four sites, while Twin Creeks had five metrics showing temporal improvement. Beyond improvement in skills among staff taxonomists, possibly resulting in an artificial improvement of some metrics (more accurate ids could increase the number of taxa), there is no easily discernible reason for this improvement. SAR was the only site to show a temporal decline in any biological measure, that of percent collector-gatherers, which is not a particularly robust measure since it tends to increase based purely on watershed size (Vannote et al. 1980). However, an increase in nutrient loads can cause these organisms to dominate the community, and with scores approaching 50%, this may be an initial indication of biological impacts to the lower watershed from increased development.

While development pressures increase in both the rural areas and urban corridor of the Onion Creek watershed, water quality appears to be fairly stable, with even some temporal improvements in the biological community. There is some indication of nutrient enrichment at lower watershed sites, but this study found little evidence of significant impacts to overall stream health. Spatial differences may be due more to ecoregion characteristics and aquifer recharge zone location rather than anthropomorphic inputs, while the presence of large undeveloped land tracts certainly mitigate urban influences.

Recommendations

- Maintain monitoring at the current six sites, representing top, middle and bottom of the catchment. While some of the distinct longitudinal differences shown between sites may be attributed to physical factors like ecoregion differences and recharge zone, monitoring at the six existing sites should be able to document changes due to differential development patterns, while continuing to characterize overall watershed patterns.

- Maintain chemical, physical and biological monitoring, per EII methodology, possibly with the addition of chlorides and sulfate. While chemical parameters indicate some temporal and spatial differences, biological communities, including diatoms, had more robust measures that showed both temporal and spatial trends.

- Reduce sampling frequency to every other year, per EII protocol. With only one decreasing water quality trend at one site (increasing dissolved ions at Hwy 150), and one metric potentially indicative of decreasing biological health at a different site (% collectors at SAR) there is not sufficient reason to continue with the intensive sampling regime.

- Discontinue weekly monitoring of E. Coli at Mckinney Falls State Park (ATCHD). There were no spatial or temporal trends seen in *E. coli* levels on Onion and the creek is fully supportive of contact recreation, as the mean of every site is below the TCEQ standard of 126 col/100 mL (Figure 11). This is of particular importance at McKinney Falls State Park, where the creek was re-opened for swimming in 1993 after many years of closures due to bacteria contamination from a now-closed wastewater treatment plant immediately upstream. City and Health department staff have fully documented current contact recreation status. Through our EII monitoring, we will be able to document any longer term trends that may occur.

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